5.5 GEOLOGIC RESOURCES AND HAZARDS

SECTION 5.5 GEOLOGIC RESOURCES AND HAZARDS CONTENTS

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5.5 GEOLOGIC RESOURCES AND HAZARDS

This section addresses the potential environmental effects on geologic resources and potential geologic hazards that may be encountered from development of the Tesla Power Project (TPP). In preparation of this section, a geologic literature search was performed and applicable documents, such as maps and reports, were reviewed. In addition, pertinent findings were incorporated from two geotechnical-engineering investigations conducted at the proposed location of the site. Copies of the geotechnical investigation reports are provided in Appendix G.

5.5.1 Affected Environment

5.5.1.1 Regional Geology and Physiography

The project site, including the plant facility, associated natural gas and wastewater pipelines, and transmission line upgrade are located in the northeastern corner of Alameda County, and a portion of San Joaquin County, along the western edge of the San Joaquin Valley, adjacent to the eastern-most foothills of the Coast Ranges. The project area falls within the Coast Range Physiographic province, and is bounded on the west by ridges that comprise the Diablo Range, and on the east by the flood plain of the San Joaquin River within the Central Valley Physiographic province (Figure 5.5-1). The Coast Ranges are a series of valleys and mountains along the West Coast of California that extend from Oregon to the Santa Ynez River near Santa Barbara. The Great Valley is a 400-mile long, northwest-southeast trending structural basin that extends along the center of the state from the Klamath Range in the north to the Tehachapi Mountains in the south (Norris & Webb, 1990).

The regional geology of the California Coast Ranges in general, is a complex system of folds and faults, largely a result of the interaction of the strike-slip tectonics of the San Joaquin fault system and the compressional tectonics of the Coast Ranges. The Coast Ranges are composed of several parallel longitudinal ranges that trend northwest. These ranges have resulted from the folding and faulting of intra-basin sediments during Miocene to Pleistocene periods. The Diablo Range is an assemblage of anticlinal folds composed largely of Cretaceous-Jurassic age Franciscan Formation marine sedimentary rocks. The San Joaquin Valley is a northwesterly trending structural basin that is filled with approximately 30,000 feet (9,150 meters) of quaternary alluvial sediments derived from erosion of the Sierra Nevada Mountains and the Coast Ranges (Harden, 1998).

The area surrounding the project site consists of highly deformed strata of the San Pablo Group (marine sandstone) dipping up to 30 degrees (Dibblee, 1980). The project site is located on the eastern flank of the Altamont Anticline, the largest fold in the area. The axis of the fold trends northwest at forty degrees west of north, much like all the structural features of the area, and plunges to the southeast (Geocon, 2001a). On both limbs of the fold, high angle faults parallel the trend of the fold. The Midway Fault, which runs along the northern boundary of the proposed plant site, is one of these northwest trending high angle faults (Geocon, 2001a).

The structure of the area is controlled by faulting, which predominately trends in a northwesterly direction, which is similar to the general structural trend of California. Most of the basement rocks in the project area were folded and faulted as a result of early convergence of the North American and Pacific plates.

The proposed power plant site is relatively flat and lies in a topographic basin within the Diablo Range foothills. The site is bordered on the south and west by hills reaching elevations in excess of 2,000 feet, and to the north and east by low hills averaging 400 to 500 feet in elevation. The major natural features in the area are low rolling hills, bluffs, and the drainage of Patterson Run approximately one-half mile south of the site. Bedrock on the site is comprised of Miocene marine and non-marine rocks of the Neroly Formation, and Pliocene nonmarine rocks of the Tulare Formation. Rocks from the Neroly and Tulare Formations form local resistant bluffs. Quaternary alluvial deposits from erosion of the surrounding hills are present in the nearby valleys and underlie the site.

5.5.1.2 Regional Tectonic Setting

The San Francisco Bay area, which is approximately 30 miles west of the project site, is characterized by regular seismic shaking and potential ground rupture. The area lies at the boundary of the North American and Pacific plates, an active predominately strike-slip plate boundary. About 10 million years ago, the tectonic regime in the area changed from convergent to a transform boundary between the North American and the Pacific Plates. The western pacific plate is moving to the northwest relative to the eastern or North American plate. This transform boundary is commonly referred to as the San Andreas Fault Zone. The San Andreas Fault takes up the main motion along this boundary, though the area of deformation ranges across to the Central Valley (Harden, 1998).

5.5.1.3 Regional Seismicity

The San Francisco Bay area has been the site of several large earthquakes during the past 2000 years. The largest of these was the 1906 Richter magnitude 8.0 earthquake of San Francisco, which was caused by movement on the San Andreas Fault. The surface rupture from the 1906 earthquake was 270 miles [432 kilometers (km)] long, and extended from Shelter Cove to San Juan Bautista. Fault movement for the 1906 quake had a right lateral displacement of approximately 20 feet (6 meters) with three feet (0.9 meters) of vertical displacement. This historic quake resulted in widespread destruction throughout San Francisco. More recently the 1989 magnitude 7.1 Loma Prieta earthquake caused a surface rupture about 22 miles (35 kilometers) long on the San Andreas Fault. This quake consisted of a right lateral slip of about 6½ feet (2 meters), and resulted in damage totaling six to seven billion dollars (Geocon, 2001a). Closer to the site, smaller magnitude earthquakes have occurred on the Hayward, Calaveras, Green Valley and Greenville fault. Although the majority of the events occurred before the turn of the 20th century, recent events have occurred on the Calaveras Fault (1984 Magnitude 6.1 and 1979 Magnitude 5.9) and the Greenville Fault (1980 Magnitude 5.6).

5.5.1.4 Local Geology

The project site is located primarily within the U.S. Geological Survey (USGS) Midway quadrangle (1:24,000). Figure 5.5-2 is a 1:24,000 scale geologic map of the site area, including the plant site, natural gas supply line, electrical transmission line, and the water pipeline. Table 5.5-1 is a stratigraphic column describing the major geologic formations in the project area. The project site and its ancillary facilities are located on map units Tn (the Neroly Formation, part of the San Pablo group), Tps (Pliocene-age non-marine sedimentary rocks, Tulare Formation), and Qa (Quaternary alluvium) (Dibblee 1980). These stratigraphic units are described below.

San Pablo Group (Neroly Formation)

The term San Pablo Group has a long history of varied use in the geological literature (e.g., Weaver 1909; Clark 1915; Patten 1947; Hall 1958; Wagner 1978). Overall, the San Pablo Group and its included formations represent both terrestrial and marine Miocene sedimentation. The deposits record fluctuations in the locations of upland or mountainous sediment sources and their related stream deposits as well as the shoreline and marine sedimentary environments these streams drained to. The various formations reflect sediment derived from both the Sierra Nevada and uplands in the vicinity of the present Coast Range and record changes in the shoreline over time.

In the project area, the Neroly Formation is the only exposure of San Pablo Group rocks (Huey 1948; Dibblee 1980). The Neroly Formation is composed of conglomerates, sandstones, shales, and volcanic ash deposits (Huey 1948). Notably, the conglomerates and sandstones are derived from the volcanic andesites of the Mehrten Formation of the Sierra Nevada (Huey 1948; Wagner 1978). As shown on Table 5.5-1, the Upper Neroly Formation predominately consists of shales estimated to be close to 2,000 feet thick (USGS 1980). Below these shales, is a series of light brownish gray to very pale brown, cross-bedded, sandstones, siltstones and pebbly sandstones. The sands vary from poorly to well sorted, and are generally subangular to surrounded.

Below the Neroly Formation lies the second member of the San Pablo group, the Cierbo Formation. The Cierbo, a transgressive formation, is the unit most often involved in the folding and faulting of the area. It consists of sandstone, white to buff in color, and is formed predominately of quartz. The contact between the Cierbo and the Neroly Formations can be either conformable or unconformable, depending on location (Dibblee, 1980).

Below the Cierbo, lie several formations that are exposed in the Midway quadrangle. Most notably are the white sands and dark brown shales of the Tesla Formation, and below that, massive sandstones, silty shales and conglomerates of the Panoche Formation. These two members make up over 12,000 feet of the sediments in the area. Basement rocks are believed to belong to the Franciscan Complex, which consist of a chaotic mixture of sandstones, shales, cherts, conglomerates, and pillow basalts (Geocon, 2001a).

Table 5.5-1. Generalized Stratigraphic Column of the Project Vicinity

Era	Age	Formation	Map Symbol	Thickness (feet)	Description
Cenozoic	Quaternary	Alluvium and landslide debris	Qa Qls	?	Gravels, sands, silts, clays
		Older alluvium	Qoa		
	Pliocene	Tulare and non-marine sedimentary rocks	Q1	100+	Continental deposits of gravels, sands, clays
			Tps	4,000	
	Upper Miocene	San Pablo Group – Neroly – Upper	Tn_{sh}	2,000+	Shales, blue sandstones, tuffs
		San Pablo Group – Neroly – Lower	Tn_{ss}	50-700	Blue sandstone, andesitic conglomerate, tuffs.
		San Pablo Group – Cierbo	Tm_{ss}	100-500	Granular white sands, tan sands, tuffs, conglomerate, and coal.
	Middle Eocene	Tesla	Tt_s	2,000	Marine units – tan sands, white sands, and clays.
					Brackish water units – tan sands, dark brown fissile shales, and coal.
Mesozoic	Upper Cretaceous	Morano	K_m	550	Upper-most unit is localized tan sandstone, siliceous, argillaceous, and sandy shales with calcareous concretions and interbedded sandstones.
		Panoche	K_{pg}	10,000+	Massive sandstone with abundant concretions, argillaceous and silty shales, conglomerates.
	Cretaceous and Jurassic	Franciscan Assemblage	KJf	15,000?	Melange – chaotic mixture of sandstones, shales, cherts, conglomerates, and pillow basalts. Glaucophane schist, serpentine, diabase, and diorite-gabbros are common.

Notes: Source (Geocon 2001a)

- - - - - - - - - - - - - - Conformable Contact (dashed where gradational)
Unconformable Contact
- · - · - · - · - · - · - · - Fault Contact

Tulare Formation

The term Tulare Formation is used on the west side of the San Joaquin Valley for all deformed nonmarine sediments overlying Pliocene marine rocks (Woodring et al. 1940; Davis and Coplen 1989). These deposits represent various alluvial fan, stream, flood basin, and lake environments. Non-marine deposits of morphologically recognizable alluvial fans or stream terraces are not considered part of the formation.

The Tulare Formation is thickest in the southern part of the valley (e.g., near the Kettleman Hills) and thins to the north (Davis and Coplen 1989). It ranges in age from Pliocene to early Quaternary in age (Woodring et al. 1940). It is recognized extensively in both the subsurface and in exposures along the western valley and easternmost Coast Range. Examination of the composition of the Tulare Formation in the subsurface has been used to evaluate the depositional history of the San Joaquin Valley including the variation over time of the influxes of sediment from the Sierra Nevada and the Coast Ranges (e.g., Davis and Coplen 1989). The Corcoran Clay Member of the Tulare Formation is a deposit of lake clays that underlies much of the San Joaquin Valley. Deposition of the Corcoran Clay began at least 725,000 years ago (Davis and Coplen 1989).

Quaternary Alluvium

Sediment deposition by streams into the San Joaquin Valley has continued from Tulare time to the present day. Currently, the streams draining the Coast Range transport sediments onto the alluvial fan surfaces and sometimes beyond into the flood basin of the San Joaquin River. Above these present streams and their recent deposits are older alluvial fan or stream terrace landforms and deposits (Lettis 1985; Sowers et al. 1992). Additionally, these stream sediments can sometimes be traced up into the Coast Range valleys; the project site includes Quaternary alluvium that fills the lower parts of the valley, although recognizable stream terraces cannot be observed. These landforms and deposits record the depositional history of these streams but also reflect the tectonic uplift history of the Coast and Diablo Range which has caused the streams to erode down into the bedrock, the San Pablo Group, and the Neroly Formation, Tulare Formation, older alluvial fan deposits (Lettis 1985; Sowers et al. 1992). The average thickness of the alluvial deposits in the vicinity of the plant site is not known, but is estimated at five to ten feet (USDA, 1966).

5.5.1.5 Local Faulting and Seismicity

The project site is located in a region of known faulting and seismicity. Several significant historically activity faults are present within 62.5 miles (100 km) of the area. Principal faults located in the vicinity of the site shown on Figure 5.5-3. The fault that is likely to have the most influence on the sight with regards to ground accelerations is the Greenville Fault, approximately 6 miles (10 km) west of the site. The Greenville Fault has been zoned as active Earthquake Fault Hazard Zone under the State of California's Alquist-Priolo Act [California Division of Mines and Geology (CDMG), 1999a]. Specifically, with respect to the project site, the Midway quadrangle is identified as "Earthquake Fault Zone".

Two faults are located within the immediate boundaries of the project site, the Midway Fault and West Side Fault (see Figure 5.5-3). The trace of the Midway Fault runs across the plant site, along the northeastern boundary of the property. The Midway Fault is a northwest trending, right-lateral strike-slip fault. The length of the fault is approximately 7 miles (11 km). Due to the close proximity of the Midway Fault to the site, a fault investigation was conducted to more accurately define the trace and activity of the Midway Fault (Geocon, 2001b). The techniques used for the investigation consisted of a review of published and unpublished literature, air photo analysis, mapping of the surface geology, a geophysical survey, and subsurface trenching. Results from the investigation confirmed that the Midway Fault runs through the northeast corner of the site. The report findings also indicate that the last significant movement (greater than five centimeters per episode) along the Midway Fault was pre-Holocene (more that 10,000 years ago), but not pre-Pleistocene (more than 2,000,000 years ago). The age of the last significant movement was between 10,000 and 40,000 years ago; therefore, the Midway Fault is considered to be potentially active (Geocon, 2001b). An active fault is defined as having historic movement (within the last 10,000 years) and a potentially active fault is defined as having movement in the Quaternary (within the last two million years).

A previously undocumented northwest trending fault (West Site Fault) was observed in the railroad cut south of the plant site during a geotechnical site assessment conducted by Geocon Inc. (2001a). Based on the Geocon's geotechnical assessment, the limited exposure of the West Side Fault did not lend itself to a determination of the age of seismicity. However, the apparent fault trace lines up with possible fault related surface features in the form of linear topographic depressions to the northeast and southwest of the cut in the railroad embankment (Geocon, 2001a). A subtle, apparently fault related depression extends southeast from the railroad cut. However, the depression may be the result of increased erosion along the fault, rather than actual movement [Geocon, 2001a, (Appendix G)].

Local seismicity at the project site is primarily influenced by the right-lateral strike-slip of the San Joaquin Fault System and the compressional tectonics of the Coast Ranges/Sierran Block boundary zone (see Figure 5.5-3). This boundary zone [approximately 300 miles long (485 km)] has been designated a "Special Seismic Source" where regional seismicity may be caused from deep-seated slip where no surface faults exist or are concealed by alluvium or complex folding (Stein and Yeats, 1989). This "Special Seismic Source" also known as the Coast Range-Central Valley (CRCV) Thrust System is located approximately one and one half miles (2.5 km) east of the site. Two significant historical seismic events have been tied to the CRCV Thrust System; specifically a 6.7 Richter magnitude event near Coalinga in 1983 and a 7.0 Richter magnitude event near Winters in 1892 (Geocon, 2001b). In addition to this special seismic source, many faults exist near the site; these faults are discussed in greater detail below.

Table 5.5-2 identifies 14 faults located within 62.5 miles (100 km) of the area, that are considered active. Six of the faults are considered type "A" faults, those with slip rates in excess of five millimeters per year (mm/yr), have well-constrained paleoseismic data, and are capable of producing an earthquake with a moment magnitude (M) of 7.0 or greater. The type "A" faults include the north segment of the Calavares Fault, the north and south branches of the Hayward Fault, the north and peninsula segments of the San Andreas Fault, and the San Gregorio Fault. Of the type "A" faults, the north segment of the Calaveras Fault, and the north and south segments of the Hayward Fault are expected to have the most effect on the site. The only type "B" faults that may have a strong effect on the site are the Greenville and Concord-Green Valley Faults. Type "B" faults are those with slip rates greater than 2 mm/yr and M greater than 6.5. The site is considered susceptible to seismicity and seismic damage due to activity on nearby faults.The Greenville Fault, located five to six miles (eight to ten kilometers) west of the site, is the fault most likely to cause seismically induced damage (Geocon, 2001a).

The San Andreas Fault, Hayward Fault, and Calaveras fault zones are historically the most active of those listed in Table 5.5-2, and are briefly described below.

San Andreas Fault

The San Andreas Fault is part of a complex system of faults, isolated segments of the East Pacific Rise, and scraps of tectonic plates lying east of the East Pacific Rise that collectively separate the North American plate from the Pacific plate (Wallace 1990). Relative movement between the Pacific and the North American tectonic plates dominates the regional seismo-tectonic setting. The boundary between the Pacific and North American plates extends from the Rivera triple junction south of Baja California, northwards to the Mendocino triple junction. Atwater (1970) and, more recently, Irwin (1990) describes the evolution of the Pacific-North American plate boundary. For much of the length of the plate boundary, and certainly for the site region, the San Andreas Fault functions as a transform fault (tectonic plate boundary) with strike-slip displacement (Wilson 1965). In the San Francisco Bay area, the relative horizontal (strike-slip) movement along this boundary is about 47 mm/yr., and is being distributed among the various faults of the San Andreas system (Petersen *et al.,* 1996). Over geologic time, the San Andreas Fault accommodates about 24 mm/yr. of this movement (Petersen *et al.,* 1996).

Hayward Fault Zone

The Hayward Fault Zone consists of one known active strand (fault) and as many as three sub-parallel strands that generally lie east of the active strand. The active strand is marked by active creep, shutter ridges, offset streams, and cultural features such as offset railroad tracks, roads, sidewalks, and building foundations etc. Evidence for parallel fault strands in the eastern part of the fault zone is less abundant. For the most part, the fault traces are defined by linear features such as topographic benches and narrow ridges (USGS, 1970).

Table 5.5-2. Known Active Faults within 100 Kilometers of TPP

Fault Name	Fault Type [1]	Fault Geometry	Distance from Sites (Approximate) Km	(miles)	Fault Length Km	Slip Rate (Approximate) mm/yr	M_{max}	R.I. Years	Estimated Duration of Shaking [2] seconds	Peak Horizontal Acceleration at Tesla Site [3] g
Greenville [4]	B	Rl-ss	9	(6)	73	2	7.2	521	15	0.47
Calaveras (north)	A	Rl-ss	29	(18)	52	6	6.8	146	14	0.17
Hayward (north)	A	Rl-ss	39	(24)	43	9	6.9	167	15	0.15
Hayward (south)	A	Rl-ss	40	(25)	43	9	6.9	167	15	0.15
Calaveras (south)	B	Rl-ss	40	(25)	106	15	6.2	33	9	0.10
Concord-Green Valley	B	Rl-ss	40	(25)	66	6	6.9	176	15	0.15
Hayward (southeast)	B	Rt-r-o	43	(27)	66	3	6.4	220	10	0.11
Monte Vista-Shannon	B	R45, E	49	(31)	41	0.4	6.8	2410	14	0.12
San Andreas (Peninsula)	A	Rl-ss	68	(43)	88	17	7.1	400	17	0.11
West Napa	B	Rl-ss	76	(47)	30	1	6.5	701	11	0.07
Rogers Creek	B	Rl-ss	77	(48)	63	9	7.0	222	16	0.09
San Gregorio	A	Rl-ss	83	(52)	129	5	7.3	400	19	0.10
San Andreas (North Coast)	A	Rl-ss	91	(57)	322	24	7.6	n/a	24	0.11
Hunting Creek-Berryessa	B	Rl-ss	95	(59)	60	6	6.9	194	15	0.07

Notes:
[1] From UBC97, Table 16-U.
[2] Bracketed duration of shaking (duration of shaking in excess of 0.05g) – approximate times for soil.
[3] Site acceleration derived using Boore, Joyner, Fumal (1997) attenuation relationship for peak horizontal acceleration for North American Earthquakes.
[4] M_{max} for the Greenville Fault is based on the Association of Bay Area Governments 1999 Earthquake Hazard Map for the Entire Bay Area, Scenario: Greenville Fault.

Km – kilometer
mm/yr – millimeters per year
M_{max} – maximum magnitude
R.I. – Recurrence Interval
ss – strike slip

r45, E – reverse fault dipping 45 degrees east
o – oblique
rl – right lateral
g – acceleration due to gravity
TPP – Midway Power Project

The Hayward Fault Zone is the southern segment of an extensive fracture zone consisting of the Hayward Fault, Rodgers Creek, Healdsburg, and Macama fault segments. The zone extends northwest to Mendocino County, a total distance of 175 miles (280 km). A 53-mile-long (86 km) Hayward Fault segment extends from San Pablo Bay to an obscure convergence with the Calaveras fault near Mount Misery east of San Jose, California.

Several segments of the Hayward Fault are undergoing fault creep, a very gradual horizontal displacement that occurs both episodically and continuously (Lienkaemper *et al.* 1991). While fault creep has been documented along many segments of the Hayward Fault between San Pablo and Fremont, it has not been observed along all segments throughout the fault's length. South of Fremont, the Hayward Fault is seismically quiet. The displacement is almost purely right-lateral although small segments have a vertical component of displacement.

Calaveras Fault Zone

The Calaveras Fault Zone is a fracture zone approximately 0.6 miles (1 km) wide. There is a significant vertical component of movement within the Calaveras fault zone, as is evidenced by at least two levels of uplift in the westernmost portion of the Diablo Range. It is estimated the total displacement along the Calaveras fault may be 10 miles in the last 3.5 million years and it could be as much as 40 miles in the last 8 million years.

5.5.1.6 Earthquake History

The largest seismic event affecting the site was the 1906 San Francisco earthquake (M 8). The epicenter of the 1906 earthquake was approximately 40 miles (65 km) west of the project area, and it was strongly felt throughout Alameda County.

Although the San Andreas Fault is of primary concern to many San Francisco Bay and Alameda County residents, the Hayward and Calaveras fault zones are active and are potential sources of major earthquakes. The U.S. Geological Survey records almost daily occurrences of seismic events along the Calaveras, Hayward, and San Andreas faults zones. People generally are not aware of most of these earthquakes, because they are so small as to be undetectable except with special equipment.

As previously mentioned, the Greenville Fault located five to 6 miles (8 to 10 km) west of the site, is the fault most likely to cause seismically induced damage. The Greenville Fault is a right-lateral strike-slip fault associated with the San Andreas Fault System. In 1980, a Richter magnitude 5.8 seismic event occurred on the Greenville Fault. The epicenter of the event was located approximately six miles west of the site, near Livermore.

The Midway Fault, a potentially active fault, runs across the site near the northeast boundary. According to the Department of Water Resources 1979 seismic hazards evaluation for Bethany Reservoir, two earthquakes have been detected near the trace of the Midway Fault since 1900. The larger of the two was a 3.5 Richter magnitude event (Geocon, 2001b).

Shown on Table 5.5-3 are recorded earthquakes of magnitude greater than 5.0 that have occurred within 63 miles (100 km) of the project site. The approximate locations of the earthquake epicenters are plotted on Figure 5.5-4. Ten earthquakes of magnitudes greater than 6 were recorded in 1836, 1838, 1858, 1868, 1890, 1897, 1898, 1911, 1984, and 1989; these events occurred in the last 163 years, for an average of one every sixteen years. The most recent seismic events in the vicinity of the site include the 1984 Morgan Hill earthquake, and the 1989 Loma Prieta earthquake.

5.5.1.7 Geologic Hazards

The most significant geologic hazard that could likely affect the project area is the risk to life and property from a large earthquake generated by the nearby Greenville Fault, which is capable of producing a magnitude 7.2.

Earthquake hazards include a number of phenomenons, such as ground shaking, surface rupture, liquefaction, subsidence and settlement, and seismically induced landslides associated with an earthquake that may produce adverse effects on human activities. The susceptibility of a site to a particular hazard is a function of a number of factors including the local geologic conditions, the magnitude and source mechanism of the earthquake, and distance to seismic sources.

The following subsections discuss the potential geologic hazards that might occur in the project area and are based on a literature search and information provided in two geotechnical site assessment/investigation reports [Geocon, 2001a & b (Appendix G)].

Ground Shaking

Seismic waves passing through earth material during an earthquake cause the ground to shake. Severe ground shaking is the most widespread and destructive aspect of earthquakes. The intensity of ground shaking depends on the distance of the earthquake epicenter to the site, the magnitude of the earthquake, site soil conditions, and the characteristic of the source.

Seismic ground shaking is the most likely seismic hazard to affect the site. The maximum strong ground motions anticipated at the site are expected to occur due to seismicity from the Greenville Fault. According to the Uniform Building Code (UBC), 1997 edition, the site is located in Seismic Zone 4. This location implies a minimum horizontal acceleration of 0.4g for use in earthquake resistant design. Mualchin and Jones (1992) produced a map of maximum credible earthquake accelerations for California; their figure for the site indicates a horizontal acceleration of 0.5g associated with seismic event along the Greenville Fault.

A probabilistic assessment was performed for the site based on data from the CDMG Open-file Report 96-08, *Probabilistic Seismic Hazard Assessment for the State of California* (CDMG 1996), the DWR Clifton report, the International Conference of Building Officials (ICBO) *Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada* (ICBO California Fault Zone Maps) and Interpolation from the CDMG's (1999b) *Seismic Shaking Hazards Maps of California*, Map Sheet 48 (MS48). The site accelerations (see Table 5.5-3) due to an earthquake on individual faults within 63 miles (100 km) of the area were

Table 5.5.3. Earthquakes within 100 km of Site with Magnitudes Greater Than or Equal to 5

Source[1]	Date				Location		Local Magnitude	Distance[2] (km)
	Year	Month	Day	Time	Latitude	Longitude		
CDMG	1881	04	10	1000	37.40	-121.40	5.90	6
CDMG	1866	07	15	0630	37.50	-121.30	5.80	8
CDMG	1899	07	06	2010	37.20	-121.50	5.80	29
PDE	1986	03	31	1155	37.48	-121.69	5.70	31
PDE	1984	04	24	2115	37.32	-121.70	6.20	33
PDE	1988	06	13	0145	37.38	-121.77	5.40	38
PDE	1979	08	06	1705	37.10	-121.50	5.90	39
CDMG	1955	09	05	0201	37.37	-121.78	5.50	39
CDMG	1911	07	01	2200	37.25	-121.75	6.60	41
CDMG	1866	03	26	2012	37.10	-121.60	5.40	43
CDMG	1891	01	02	2000	37.30	-121.80	5.50	43
CDMG	1903	08	03	0649	37.30	-121.80	5.50	43
CDMG	1903	06	11	1312	37.60	-121.80	5.50	44
PDE	1993	01	16	0629	37.03	-121.46	5.30	46
CDMG	1949	03	09	1228	37.02	-121.48	5.20	47
CDMG	1864	02	26	1347	37.10	-121.70	5.90	48
PDE	1980	01	27	0233	37.74	-121.74	5.80	49
CDMG	1897	06	20	2014	37.00	-121.50	6.20	49
CDMG	1858	11	26	0835	37.50	-121.90	6.10	50
CDMG	1865	10	08	2046	37.30	-121.90	6.30	51
CDMG	1964	11	16	0246	37.06	-121.69	5.00	51
CDMG	1865	05	24	1121	37.10	-121.80	5.50	54

Table 5.5.3. Earthquakes within 100 km of Site with Magnitudes Greater Than or Equal to 5 (Continued)

Source[1]	Date				Location		Local Magnitude	Distance[2] (km)
	Year	Month	Day	Time	Latitude	Longitude		
CDMG	1959	03	02	2327	36.98	-121.60	5.30	54
PDE	1988	06	27	1843	37.13	-121.88	5.70	58
PDE	1989	10	25	0127	37.08	-121.83	5.00	58
PDE	1974	11	28	2301	36.91	-121.50	5.20	59
PDE	1989	10	18	0025	37.04	-121.81	5.00	59
CDMG	1882	03	06	2145	36.90	-121.20	5.70	60
CDMG	1967	12	18	1724	37.00	-121.78	5.30	61
PDE	1980	01	24	1900	37.85	-121.82	5.90	62
PDE	1989	08	08	0813	37.13	-121.95	5.40	63
PDE	1990	04	18	1341	36.92	-121.67	5.00	63
PDE	1990	04	18	1546	36.93	-121.69	5.20	63
CDMG	1883	03	30	1545	36.90	-121.60	5.60	63
CDMG	1890	04	24	1136	36.90	-121.60	6.00	63
CDMG	1954	04	25	2033	36.93	-121.68	5.30	63
PDE	1990	04	18	1353	36.92	-121.68	5.40	64
PDE	1989	10	18	0004	37.04	-121.88	7.10	65
CDMG	1864	03	05	1649	37.70	-122.00	5.70	65
CDMG	1914	11	09	0231	37.17	-122.00	5.50	65
CDMG	1899	04	30	2241	36.90	-121.70	5.60	66
CDMG	1963	09	14	1946	36.87	-121.63	5.40	67
CDMG	1864	05	21	0201	37.60	-122.10	5.30	69
CDMG	1861	07	04	0011	37.80	-122.00	5.60	71
CDMG	1910	03	11	0652	36.90	-121.80	5.50	71

Table 5.5.3. Earthquakes within 100 km of Site with Magnitudes Greater Than or Equal to 5 (Continued)

Source[1]	Date				Location		Local Magnitude	Distance[2] (km)
	Year	Month	Day	Time	Latitude	Longitude		
PDE	1989	10	18	0041	37.20	-122.11	5.10	72
CDMG	1870	02	17	2012	37.20	-122.10	5.80	72
CDMG	1868	10	21	1553	37.70	-122.10	6.80	73
CDMG	1889	05	19	1110	38.00	-121.90	6.00	80
CDMG	1885	03	31	0756	36.70	-121.30	5.50	81
CDMG	1884	03	26	0040	37.10	-122.20	5.90	84
CDMG	1856	02	15	1325	37.50	-122.30	5.50	85
CDMG	1836	06	10	1530	37.80	-122.20	6.80	86
CDMG	1889	07	31	1247	37.80	-122.20	5.20	86
CDMG	1955	10	24	0410	37.97	-122.05	5.40	86
CDMG	1926	10	24	2251	37.02	-122.20	5.50	88
CDMG	1838	06			37.60	-122.40	7.00	95
CDMG	1870	04	02	1948	37.90	-122.30	5.30	99

Notes:

(1) CDMG California Division of Mines and Geology (Real and others, 1978).
PDE Preliminary Determination of Epicenters from NEIS/CGS.

(2) "Distance in kilometers" is equal to the radial distance from the site.

derived using the Boore, Joyner, Fumal attenuation relationship for peak horizontal acceleration for North American Earthquakes. The calculated peak acceleration on the Greenville Fault is 0.47 g, the Calaveras Fault gave a calculated peak acceleration of 0.17g. and the north and south segments of the Hayward Fault each contributed a 0.15g acceleration on the site. The calculated peak acceleration agrees with the peak acceleration derived from MS48 that shows a 10 percent probability in 50 years of an earthquake causing ground accelerations in the area exceeding 0.4g to 0.5g.

Ground Rupture

Surface ground rupture along faults is generally limited to a linear zone a few meters wide. There are two faults that can affect the project site in regards to potential ground rupture, the Midway Fault and the West Side Fault. The location of the Midway Fault with respect to the proposed plant site is illustrated on Figure 5.5-5. As shown on Figure 5.5-5 the trace of the Midway Fault runs northeast across the site. The primary hazard posed by the Midway Fault is surface rupture. Based on statistical relationships the maximum potential displacement on the fault is 1 to 3 feet with a maximum moment magnitude of 6.3 (Geocon, 2001b). Consequently, a 50-foot setback from the fault and associated shear zone will be established for the construction of critical and occupied structures.

The West Side Fault, a smaller officially unnamed fault shown on Figure 5.5-2, was discovered in a railroad cut south of the plant site by Geocon (2001a). The age or possible seismicity/activity of the West Side Fault has not been established.

Liquefaction

Liquefaction is a process by which water-saturated materials (including soil, sediment, and certain types of volcanic deposits) lose strength and may fail during strong ground shaking. Liquefaction is defined as "the transformation of a granular material from a solid state into a liquefied state as a consequence of increased pore-water pressure" (Youd, 1992). This behavior is most commonly induced by strong ground shaking associated with earthquakes. In some cases, a complete loss of strength occurs and catastrophic ground failure may result. However, liquefaction may happen where only limited strains develop, and ground surface deformations are much less serious.

There are four types of ground failure or collapse of soil structures that commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength. The sediments underlying project site are considered to have a low potential for liquefaction (ABAG, 2001). Further, the depth to bedrock (Neroly Formation) is approximately between 1 to 12 feet bgs. Well logs for the area surrounding the site, indicate that the static groundwater level west of the Midway Fault lies at a depth of 25 to 30 feet bgs, while the single well log found east of the Midway Fault reports a static water level of 85 feet bgs. Lastly, no liquefaction features were observed at the site during the geotechnical assessment (Geocon, 2001a). Based on the site geology, depth to groundwater, and absence of liquefaction features, there is a low potential for the effects of lateral spread, ground oscillation and loss of bearing strength to be experienced in the event of a major earthquake.

Subsidence and Settlement

Land surface subsidence can be induced by both natural and human phenomena. Natural phenomena include: subsidence resulting from tectonic deformations and seismically induced settlements; soil subsidence due to consolidation, hydrocompaction, or rapid sedimentation; subsidence due to oxidation or dewatering of organic-rich soils; and, subsidence related to subsurface cavities. Subsidence related to human activity includes subsurface fluid or sediment withdrawal. Underground mining may also cause subsidence, but that is not a factor at this locality.

No evidence of subsidence has been documented in the region surrounding the project area. Further Geocon (2001a) observed no subsidence features at the site during the field reconnaissance.

Due to the relatively loose, unconsolidated, nature of the Quaternary alluvial deposits, there is a potential for soil settlement to occur at the site. Settlement would primarily be a consequence of an increase in overlying pressure from the construction of structures associated with the plant site.

In the event of a major earthquake, it is unlikely that subsidence and settlement would occur because of the low potential for ground failure resulting from liquefaction.

Slope Stability

Slope instability depends on steepness of the slope, underlying geology, surface soil strength, and moisture in the soil. Slope stability is not expected to be a significant concern. No slumps, slides, rock falls, or evidence of soil creep was observed during the field reconnaissance performed by Geocon (2001a). In addition, no landslide features were identified on aerial photos or geologic maps for the project site.

Expansive Soils

Expansive soils shrink and swell with wetting and drying. The shrink-swell capacity of expansive soils can result in differential movement beneath foundations. Soil present at the plant site is predominately a calcareous clay loam exhibiting good drainage and a low shrink-swell potential (USDA, 1966). Geocon (2001a) did not observe evidence of highly expansive soils at the site.

5.5.1.8 Geological Resources

Based on a review of geologic literature, topographic maps and findings presented in Geocon's site assessment report (Geocon, 2001a), there is no indication that geologic resources (mineral deposits, sand and gravel deposits, etc) are associated with the project area. Regionally, sand and gravel quarries and natural gas fields are the primary geologic resources and are located in the Livermore and San Joaquin valleys. The closest operating sand and gravel mining operations are approximately 10 miles east near City of Tracy (CDMG, 1999c). The soils and bedrock at the site are unlikely to be a source of construction material because they contain too many fines for use as sand or gravel (USDA, 1966). The nearest operating gas fields are located approximately 5 miles northeast of the City of Tracey (Munger 1994).

Recreational geologic resources typically include rock or mineral collecting, volcanoes, surface hydrothermal features, or surface expression of geologic features unique enough to generate recreational interests of the general public (e.g., natural bridges, caves, and geomorphic features such as waterfalls, cliffs, canyons, and badlands). Based on a review of geologic literature and topographic maps, there is no indication that recreational geologic resources are associated with the project area.

5.5.1.9 Project Site

Site Geology

The project site is underlain by Quaternary alluvial deposits, which are derived from erosion of the surrounding hills, which are mapped as the Neroly and Tulare Formations. Traces of the Midway Fault and West Side Fault are located in the boundaries of the project site. The Midway Fault is an active to potentially active fault. The age and earthquake potential for the West Side Fault has not yet been established. Additional details regarding the site geology is provided in the geotechnical assessment conduct by Geocon (2001a) and presented in Appendix G.

Liquefaction

According to Geocon (2001a), the liquefaction potential of the site is low.

Geological Resources

There are no known mineral resources associated with the project area. Surface soils are unlikely to be a source of construction material because they contain too many fines for use as sand or gravel (USDA, 1966).

5.5.1.10 Natural Gas Pipeline Route

The natural gas pipeline route is shown on Figure 5.5-2, Geological Map of Site and Vicinity. The pipeline will be excavated through surface soils and Quaternary alluvial deposits. Quaternary alluvium includes gravel, sand, and silt deposited by slopewash and intermittent streams.

5.5.1.11 Transmission System Upgrade

The transmission lines are illustrated on Figure 5.5-2. The transmission lines will be excavated through surface soils and Quaternary alluvial deposits. Quaternary alluvium includes gravel, sand, and silt deposited by slopewash and intermittent streams.

5.5.2 Environmental Impacts

Appendix G of CEQA addresses significance criteria with respect to geological resources (Public Resources Code Sections 21000 et seq.). The project would have a significant environmental impact on geologic resources and hazards if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map.
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides
- Result in substantial soil erosion or the loss of topsoil
- Be located on a geologic unit or soil that is unstable or that would become unstable as a result of the project, and potentially result in on-or off-site landslide, lateral spreading, subsidence, liquefaction or collapse.
- Be located on expansive clays creating substantial risks to life or property.
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems.
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state.
- Result in the loss of availability of a locally important mineral resource recovery site delineated on a local plan, specific plan or other land use plan.

The potential environmental impacts from construction and operation of the site on geologic resources and risks to life and property from geologic hazards are presented in the following subsections.

5.5.2.1 Construction

Construction-related impacts to the geologic environment primarily involve terrain modification (cuts, fills, and drainage diversion measures). Preparation of the ground surface at the power plant site will involve minor grading, leveling, and filling. The plant site will occupy 25 acres of land. The site will be graded to achieve a minimum one percent slope to promote surface drainage and minimize soil erosion, and areas adjacent to equipment will be surfaced with asphalt or crushed rock. Specific drainage and erosion control measures to be practiced during site construction are presented in the geotechnical report provided in Appendix G. If there is excess material that cannot be used, it will be disposed of at a suitable location offsite. Site grading will not result in significant adverse impacts to the geological environment.

The plant site is situated on Qa (Quaternary alluvium) deposits. These sediments may require some additional drainage measures; otherwise, they present minimal problems for preparation of a level surface on which to construct the power plant. Soil present at the plant site is predominately a calcareous clay loam exhibiting good drainage and a low shrink-well potential (USDA, 1966). Further, Geocon (2001) observed no evidence of highly expansive soils at the site; consequently, soil expansion is not considered a significant hazard at the project site.

The plant site, wastewater and natural gas pipelines, and transmission upgrade are located in the Midway topographic quadrangle, which is designated an "Earthquake Fault Zone" by the Alquist-Priolo Act (CDMG, 1999a). This designation is attributed to the presence of the Greenville Fault zone, which is located in approximately 6 miles (9 km) west of the project site. Earthquake Fault Zones are delineated to define those areas within which fault-rupture hazard investigations are required prior to building structures for human occupancy (CDMG, 1997). Because the plant site is intended for human occupancy, a fault-rupture hazard investigation will be conducted.

The findings provided in Geocon's fault investigation report (Appendix G) indicate the Midway Fault crosses the northeast corner of the proposed plant site. There is a potential for a moderate size earthquake to occur on the Midway Fault, which may result in strong ground shaking and/or surface rupture. A 50-foot setback from the Midway Fault and associated shear zone will be established for the construction of critical and occupied structures. The shear zone extends westward 35 feet from the main trace of the Midway Fault. The recommended setback extends 50 feet west from the shear zone edge and 50 feet east from the main trace of the Midway Fault. The total structural exclusion zone is 135 feet wide, paralleling the Midway Fault. The setback zone is shown on Figure 5.5-5. The pipelines and transmission lines will cross the fault perpendicular to the fault trace to minimize the potential for damage. Further, the TPP will be designed and constructed in accordance with the UBC (1997) seismic design criteria to mitigate these potential hazards. Seismically related ground failure from liquefaction is not anticipated due to the depth of groundwater, which is greater than 25 feet below ground surface. In addition, landslides are not anticipated in the surrounding hills. No slumps, slides, rock falls, or evidence of soil creep was observed during the field reconnaissance performed by Geocon (2001a). In addition, no landslide features were identified on aerial photos or geologic maps for the project site. Seismic hazards and potential adverse foundation conditions will be minimized by conformance with the recommended seismic design criteria of the UBC (1997).

Construction of the proposed plant site and ancillary linear facilities is not expected to negatively impact mineral resources since there are no known mineral resources associated with the project area (CDMG, 1999c). In addition, soil at the site is not considered potential sand or gravel resource because it contains too many fines (USDA, 1966).

5.5.2.2 Operation

The project structures and equipment will be designed in accordance with UBC Seismic Zone 4 requirements. Compliance with the UBC (1997), seismic zone 4 requirements will minimize the exposure of people to the risks associated with large seismic events. In addition, the major structures will be designed to withstand the strong ground motion of a design earthquake. A design earthquake is the postulated earthquake that is used for evaluating the earthquake resistance of a particular structure. Because the seismic hazard in the region of the project area is relatively well defined, the design earthquake would be established by the maximum, or characteristic, magnitude earthquake that can potentially occur on nearby faults identified on Table 5.5-2. The plant arrangement is such that no major structures or equipment are within the projected trace of any active or potentially active faults. The plant site location is not prone to landslides, subsidence, settlement, or other geologic hazards. The operation of the project will not result in a loss of geologic resources.

5.5.3 Mitigation Measures

The TPP is not expected to result in any significant adverse impacts to geologic resources, or cause any significant adverse impacts due to geologic hazards. Therefore, no mitigation measures are required. Nonetheless, the Applicant will implement measures as discussed in this section.

Modification of existing topography is an unavoidable impact associated with the construction of the facility. However, these modifications will not destroy any unique geologic or topographic features.

Potentially adverse foundation conditions such as expansive or otherwise unsuitable foundation soils, perched water tables, and corrosive soils can be mitigated through appropriate design and construction of the facility in accordance with the recommendations in the Geotechnical Reports (Appendix G). Likewise, seismic hazards can be minimized through the implementation of the recommended seismic design criteria, and are further defined in Appendix A titled, "Structural and Seismic Engineering Design Criteria".

An engineering geologist(s), certified by the State of California, will be assigned to the project to carry out the duties required by the UBC, Section 70006 Grading Permit Requirements, including preparation of an Engineering Geologic Report, and to monitor geologic conditions during construction, approve actual mitigation measures used to protect the facility from geologic hazards, and prepare the final Geologic Grading Report.

5.5.4 Significant Unavoidable Adverse Impacts

All impacts associated with geologic hazards and geologic resources are temporary and/or insignificant in nature. Therefore, no significant unavoidable adverse impacts are expected as a result of the TPP.

5.5.5 Cumulative Impacts

The project site will be constructed to the requirements of UBC Seismic Zone 4. Site-specific geotechnical investigations would be performed prior to final design and construction. No other nearby facility or project has common geological resources that would be impacted by project site; therefore, site would not cause or contribute to significant cumulative impacts from geologic hazards.

5.5.6 Applicable Laws, Ordinances, Regulations and Standards (LORS)

Design, construction and operation of the TPP including transmission lines, pipelines, and ancillary facilities will be conducted in accordance with all LORS pertinent to geologic resources or hazards. Unless specifically stated otherwise, the design of all structures and facilities will be based on the laws, ordinances, codes, specifications, industry standards and regulations, and other reference documents in effect at the time of design. Applicable codes and industry standards with respect to the project's engineering geology are summarized in sections of Appendix A, "Foundations and Civil Engineering Design Criteria", and Appendix B, "Structural and Seismic Engineering Design Criteria".

5.5.7 Involved Agencies and Agency Contacts

Several agencies are involved with geologic hazards and resources. These include the Regional Water Quality Control Board-Central Valley Division, the California Division of Mines and Geology (CDMG), and the County of Alameda. The agency contacts are shown in Table 5.5-4.

Table 5.5-4. Involved Agencies and Agency Contacts

Agency/Address	Contact/Telephone	Permits/Reason for Involvement
Alameda County Planning Department 399 Elmhurst Street Hayward, CA 94544	Jim Sorenson Planning Director (510) 670-5400	Building, Grading and Erosion Control Permits.
Department of Mines and Geology 801 K Street Sacramento, CA 95814	State Geologist (916) 445-1923	Information regarding geologic resources and hazards.

5.5.8 Permits Required and Permit Schedule

Permits required and permit schedule for matters dealing with geologic resources and hazards for the TPP are provided in Table 5.5-5.

Table 5.5-5. Permits Required and Permit Schedule

Permit	Schedule
Grading Permit	30 days prior to start of construction activities.
Building Permit	Submit application 2 months prior to start of construction.

5.5.9 References

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